Division of Agricultural Sciences
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AVOCADO ROOT ROT

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PHYTOPHTHORA ROOT ROT OF AVOCADO

is a disease caused by a soil fungus, *Phytophthora cinnamomi,* known commonly as the avocado root rot fungus or as the cinnamon fungus. This soil organism, first described on cinnamon trees in Sumatra in 1922, is now known to attack more than 190 species of plants. Avocado root rot is the most serious disease affecting avocado trees in many parts of the world. It has affected an estimated 5,000 acres of avocado trees in California, and has been found in Butte, Fresno, Los Angeles, Orange, Riverside, Santa Barbara, San Bernardino, San Diego, Tulare, and Ventura counties.

This circular tells how to recognize the disease and what you should know about the fungus (page 3), how to detect the fungus (pages 4 and 5), and what plants the fungus attacks (page 6). It outlines what is known about measures that will prevent development and spread of the disease (pages 6 to 11) and what can be done to control root rot after it has invaded the grove (pages 11 to 16).

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The cover photo shows an avocado tree affected by avocado root rot.

AVOCADO ROOT ROT

An avocado planting will develop root rot if the soil contains the fungus *Phytophthora cinnamomi,* and if there are periods of excess soil moisture. Both of these conditions must be present, or root rot will not develop. The fungus commonly becomes active as a result of poor internal soil drainage, but may also become troublesome on better-drained soils because of breaks in water lines, overirrigation, or excessive rainfall. Drainage may be slow because of an impervious layer under the surface soil or because the entire soil profile contains considerable clay, or because strata of different textures interfere with internal soil drainage.

HOW TO RECOGNIZE ROOT ROT

Leaves of infected trees are smaller than normal, usually pale or yellow green instead of dark green, often wilted; they drop, and give the tree a sparse appearance (as shown in the photo on top of page 4). New growth is often absent; if new leaves are formed they do not develop normally and are pale green. In advanced stages of the disease, branches die back and fruit is often small. Diseased trees will frequently set an abnormally heavy crop of fruit because the loss of many roots has a partial girdling effect. Trees of any size, from nursery trees to large, old trees, may be affected.

Many of the small feeder roots on diseased trees are blackened, brittle, and dead. In advanced stages of the disease it is difficult to find feeder roots. The absence of the feeder rootlets prevents the uptake of moisture, hence the soil under diseased trees tends to stay wet.

WHAT YOU SHOULD KNOW ABOUT THE FUNGUS

The avocado root rot fungus is known as a water mold because it thrives in wet places. It is a minute form of plant life which needs wet soil for the best development of its three spore stages: **Sporangia,** which release swimming spores (zoospores); **Resistant spores** (oospores); and **Chlamydospores.**

These spore types are too small to be seen by the naked eye. (See enlargement on page 4.) Approximately ten million zoospores could be placed in an area 1-inch square. The fungus requires water to form and liberate its spores, to germinate, and to infect the roots. Sporangia, the most important spore-forming bodies, are formed at relatively high soil temperatures, mainly between 77° F and 87° F. This indicates that the major infection takes place during the warmer months of the year. The fungus makes no growth below 50° F or above 93° F. The fungus can increase very rapidly because sporangia are produced in great abundance in the soil and many swimming spores are released from each sporangium. Avocado roots susceptible to root rot exude a chemical that attracts the small swimming spores of the fungus. The substance obviously plays an important role in infection and may have some relation to resistance.

Oospores are thick-walled spores resistant to adverse conditions. They occur in diseased roots to a limited extent, and are involved in survival of the fungus over long periods. Chlamydospores are spherical spores with walls of medium thickness, and have been found in diseased roots and in soil. With oospores, they are involved in survival. Neither oospores or chlamydospores are highly resistant to drying, however; if a sandy loam soil reaches a moisture of 3 per cent for 2 weeks they do not survive.

Sporangium, the principal spore stage of the avocado root rot fungus. enlarged approximately 1,000 times. It releases from 20 to 30 zoospores which swim through water in the soil, germinate on and infect avocado roots.

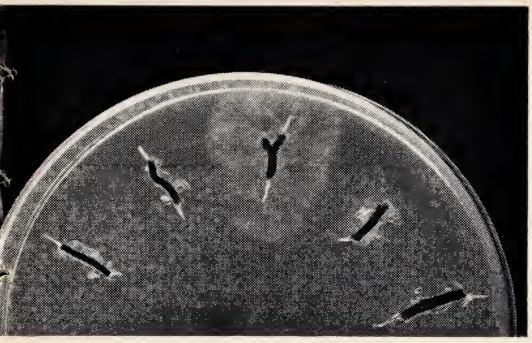
◀ Young avocado tree in advanced stage of root rot.

HOW TO DETECT THE FUNGUS

The fungus can be identified in the laboratory by making laboratory cultures of small feeder roots on cornmeal agar or other selective media. Small blackened feeder roots are selected from a soil sample, placed in a beaker of tap water, dipped briefly in 70 per cent ethyl alcohol, blotted on a paper towel, and put on cornmeal agar or an antibiotic agar medium in Petri dishes.

A practical method of isolating the fungus is to place a mature, firm avocado fruit (Fuerte or similar green fruit) in a waxed paper cup containing a soil sample. Flood the surface of the soil with water and leave the fruit on the soil for 4 days (see photo. page 5). Then remove the fruit from the soil, wash it, and leave it at room temperature for several days. If the root rot fungus is present, firm brown to pur-

Culture of avocado root rot fungus.



Above, laboratory method of detecting avocado root rot fungus. One of the five small avocado roots placed on cornmeal agar shows typical growth of the fungus.

plish-brown spots will develop at the water line on the fruit 4 to 6 days after placing the fruit in the infested soil. Positive identification of the fungus requires placing bits of tissue from these discolored spots on cornmeal or antibiotic agars, in Petri dishes, and observing subsequent growth of the fungus under the microscope. So few other fungi will attack firm, unwounded avocado fruit, however, that development of spots as pictured is proof for all practical purposes that the root rot fungus is present.

In many cases the fungus may be present on healthy-appearing trees on the margin of infested areas, and its presence can be detected only by taking root and soil samples for testing.

To check a suspected tree

Take several cupfuls of soil from three or four locations around the tree. Mix these samples and take out two to three cupfuls to be sent to a laboratory. Samples should include soil and small feeder roots taken from a moist part of the root zone from the upper 6 inches of the soil. Place samples in small polyethylene bags to prevent drying out before the cultures are made. Keep samples in a cool place until cultures or fruit tests have been made.

Several commercial laboratories are available for making tests for the root rot fungus. Your University of California Farm Advisor office will be able to tell you where such tests may be made.

Caution: Remember that positive detection of this soil fungus is difficult, especially where infestation is light. A very small amount of the fungus may be present even though the laboratory test is negative. If in doubt whether the fungus is present, recheck questionable trees.

Below, a practical method of detecting the fungus consists of placing an avocado fruit in a soil sample (as shown in left photo). If the fungus is present, brown spots will appear on the fruit in 4 to 6 days. Below, healthy fruit (left) compared with two showing presence of the fungus.

WHAT PLANTS DOES THE FUNGUS ATTACK?

In addition to avocado, the fungus attacks a wide variety of other plants which can serve as sources of infection for the avocado grove. For example, if you bring a camellia affected with the fungus onto your property, the fungus could spread from the diseased camellia and start root rot in your avocado grove. Some plants infected by the fungus in the field or nursery are:

Common name	Scientific name
Apricot	*Prunus armeniaca*
Arborvitae	*Thuja* sp.
Avocado	*Persea americana*
Azalea	*Rhododendron* sp.
Birch	*Betula* sp.
Camellia	*Camellia* sp.
Cedar,	
Incense	*Calocedrus decurrens*
Port Orford	*Chamaecyparis lawsoniana*
Deodar	*Cedrus deodara*
Chestnut, American	*Castanea dentata*
Cypress,	*Cupressus* sp.
Italian	*C. sempervirens*
Fir	*Abies* sp.
Heather	*Erica* sp.
Larch,	
Japanese	*Larix leptolepis*
European	*L. decidua*
Locust, black	*Robinia pseudoacacia*
Myrtle, compact	*Myrtus communis*
Oak	*Quercus* sp.
Peach	*Prunus persica*
Pine	*Pinus* sp.
Monterey	*P. radiata*
Scots	*P. sylvestris*
Shortleaf	*P. echinata*
Pineapple	*Ananas comosus*
Plum	*Prunus* sp.
Pomegranate	*Punica* sp.
Rhododendron	*Rhododendron* sp.
Spruce	*Picea* sp.
Walnut,	
Eastern black	*Juglans nigra*
Persian	*J. regia*
Yew	*Taxus* sp.

HOW TO PREVENT ROOT ROT

The best control for avocado root rot is to prevent the introduction of the fungus into your orchard. Diseased nursery stock has undoubtedly been mainly responsible for the wide distribution of the fungus throughout the avocado-producing areas of southern California. A soil fungus of this type can be readily transported with balled or container-grown plants. It can also be spread or introduced to new areas by infected seed, movement of infested soil and movement of water containing spores. Research indicates that the avocado root rot fungus is not native to southern California soils. You can prevent its invading your nursery or orchard by several methods discussed here.

GROW DISEASE-FREE NURSERY STOCK

A program to certify avocado nursery stock as being free from avocado root rot is available for nurserymen. This program was initiated by the avocado growers of California and developed through cooperation between the State Department of Agriculture, Division of Nursery Service, and the University of California. The basic program as outlined below consists of three parts:

- Heat treatment of seeds.
- Fumigation or steam treatment of the soil.
- Good sanitation.

Hot water treatment equipment at Santa Paula (top). Over 50,000 avocado seeds were treated here during the 1966 season. After hot-water treatment and rinsing in cold water, avocado seeds should be dried on a clean surface not in contact with the ground (lower photo).

For further information contact your local Agricultural Commissioner or Farm Advisor.

Use clean seed

The fungus can be spread in avocado seed if the fruit from which the seed is taken is allowed to remain for several days on soil infested with the fungus. Take all seed used for planting from fruit picked from the tree, or treat it with hot water (see photo, page 7).

Immerse all avocado seed that is picked off the ground, or that was placed in boxes that may have contained the fungus, in a hot-water bath at 120° F to 122° F for 30 minutes. Be certain that your thermometer is accurate, because temperatures of 125° F and greater will reduce germination.

Hot-water treatment is simple and inexpensive, and does an excellent job of killing the fungus because the plant can stand more heat than the fungus. A 100–200 gallon tank will allow you to control the temperature easily, but for small numbers of seed the kitchen sink or some similar container is useful. Use a circulating pump or a wooden paddle to agitate the water bath. One nursery has used an old bathtub with a circulating pump and two water heaters linked together. A trickle of steam or water several degrees above 120° F may be used to keep the temperature within the required range. Coarse cloth bags or wire screen containers may be loosely filled to hold the seeds during immersion. Bags or wire containers that are too full will prevent the hot water from adequately circulating around all the seeds. An efficient hot-water treatment facility is available at the County Agricultural Commissioner's office in Santa Paula.

After the hot-water treatment, immediately rinse the seeds with clean, cold running water, then spread them out to dry thoroughly on a clean surface not in contact with the ground.

Several nurseries have had excellent success with the hot-water avocado seed treatment and have shown that it is commercially feasible.

Fumigate or steam nursery soil for container-grown plants

Container-grown material, particularly with open bottoms (such as tarpaper bands) should be grown on clean benches or raised slabs to avoid any possible infection from the soil. It would be worse than useless to treat seed and soil and then place plants on soil infested with the fungus, because the pathogen will grow through treated soil more rapidly than untreated soil provided it gets there before other competing organisms.

Soil fumigation or steaming will insure soil free of the fungus. Methyl bromide is an effective fumigant when used under a plastic cover at a dosage of 3 pounds per 100 cubic feet of soil for 24 hours. Steaming soil to 180° F for 30 minutes is also effective in killing the fungus. The treatment can be done before or after the soil is placed in the containers. A very satisfactory method has been to treat the filled containers in place on the slabs or raised benches with methyl bromide. In this procedure the whole area, containers and walkways, is covered by a polyethylene plastic tarp, and the gas is injected underneath the tarp. A profitable side effect from fumigation is the killing of many weed seeds that are present in the soil mix. Seed can be planted from one to two weeks after removing the tarp.

Practice sanitation

In addition to the seed and soil treatments, strict adherence to sanitary growing conditions is absolutely necessary. To comply with the regulations for production of certified nursery stock it is also necessary to fence the entire area. Because an area can be infected in many ways, such as mud on shoes, tools, or hoses, all personnel in the nursery area must practice the utmost cleanliness possible. Keep the walkways clean; keep hose nozzles and equipment off the ground and in the fenced nursery area.

Use equal care in selecting ornamental plants for planting on avocado property. As previously mentioned, the fungus at-

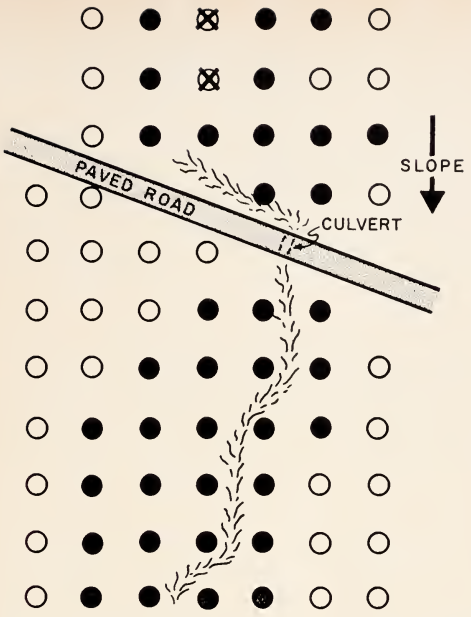


Diagram of an actual case of spread of avocado root rot fungus downhill in water. Black dots are new infections resulting from spread from two infected trees (X). Movement is more gradual in other directions than it is downhill with drainage water.

tacks many other woody plants and can be brought to a property in infected stock.

PREVENT MOVEMENT OF SOIL OR WATER FROM INFESTED AREAS

Take all precautions to prevent movement of soil or water from diseased areas into noninfested groves. The fungus can be moved by any means by which moist soil is moved—on cultivation equipment, trucks, cars, shovels, soil augers, and shoes. The fungus has been recovered from mud scraped from shoes worn in infested soil.

The fungus also can be spread downhill from an infested area by surface or subsurface drainage water, because the swimming spores are readily moved in water. Watertight drains should be installed to take care of surface runoff if a diseased area lies above a healthy grove. If gophers are active in a grove their runs may serve as good avenues of movement of the fungus, particularly its movement downhill in water. This is another good reason for gopher control.

Where possible, make cooperative arrangements with neighboring avocado growers so that drainage from diseased trees does not run over into healthy groves owned by someone else.

Small pieces of equipment, such as shovels, augers, trowels, should be washed well after use around diseased trees, and dipped in alcohol or formaldehyde solution. A 70 per cent solution of methanol, ethanol, or rubbing alcohol can be used. Dilute commercial formalin or formaldehyde to make a 5 per cent solution. Always use cultivation equipment in the healthy portion of the grove before using it in the diseased portion. Wash and allow equipment to dry thoroughly after use in the diseased section.

KNOW YOUR AVOCADO SOIL

A grove will usually show much less tree damage from avocado root rot if trees are planted on soils having good internal drainage. These are soils in which water moving through the soil is not stopped within 5 feet of the surface. Clay layers in the subsoil, a dense rock substratum within 2 or 3 feet of the surface, or clay texture from the surface to 3 or more feet will cause a soil to become poorly drained.

Statewide surveys have shown that avocado root rot damage is closely correlated with soil series. A soil series is a group of soils with similar characteristics, usually named for the area where first described, such as Ramona, Porterville or Vista series. Root rot has been most severe on those soils with characteristics which result in poor internal drainage.

In the list on page 10, many of the soil series in which avocados are grown in California are grouped according to the hazard for root rot development.

Severe hazard soils generally have a slow to very slow subsoil permeability, are poorly to very poorly drained, are less

than 36 inches deep, or have clay textures.

Moderate hazard soils include those with a moderately slow subsoil permeability, are somewhat poorly drained, are 36 to 60 inches deep and have clay loam textures.

Soils with only a slight hazard for root rot development have a rapid to moderate subsoil permeability, are excessively to well drained, are over 60 inches deep and have sand to loam textures.

Occasionally trees have been killed by root rot on internally well-drained alluvial soils, such as Yolo, which may be stratified with silt layers. These layers will cause the soil to become temporarily water-logged. On the other hand, proper management practices have appreciably reduced root rot damage on upland soils such as the Las Posas and Fallbrook series.

Using soil maps to differentiate the soils is a good guide, but is only the first step; survey each property individually. Dig holes with an auger, soil tube, or shovel throughout the area, especially in low spots.

Before planting a new grove

It is especially important to locate the problem soils—these areas can be planted to some resistant crop.

SOILS AND AVOCADO ROOT ROT DAMAGE
ROOT ROT HAZARD RELATED TO SOIL SERIES

SEVERE HAZARD

Aliso	Huerhuero	Rocklin
Altamont	Madera	San Joaquin*
Bonsall	Merriam	Santa Lucia
Cibo	Milpitas	Sespe
Clear Lake	Montezuma	Sweeney
Cometa	Olivenhain	Tierra
Diablo	Placentia	Twin Oaks
Dublin	Porterville	Watsonville
Escondido	Rincon	Zaca

MODERATE HAZARD

Ballard	Las Posas	San Andreas-Tierra
Botella	Naciamento	San Benitc
Carpenteria	Ojai	Sobrante
Chino	Pleasanton	Soper
Conejo	Ramona	Zamora
Fallbrook	Salinas	

SLIGHT HAZARD

Baywood	Marina	Vina
Elder	Metz	Visalia
Greenfield	Mocho	Vista
Hanford	Sorrento	Yolo
Honcut	Tujunga	

* If hardpan is properly ripped this soil has only moderate hazard.

In orchards already infected

Knowing the extent or boundaries of the various soil series will help you to decide how and where to retard the spread of the disease. The local University of California Farm Advisor and representatives of the Soil Conservation Service are available to help determine which soils are best suited for avocado culture and to suggest the best management practices for your soils.

Note. Good trees are found growing in almost all the soil series listed on page 10, but the possibilities of extensive tree damage from avocado root rot are greatly increased if the fungus is introduced in the soils listed as "Severe hazard" to root rot development.

HOW TO CONTROL ROOT ROT

If root rot fungus has invaded a grove, control measures will depend on the size of the infected area.

CONTROLLING SMALL SPOTS OF INFECTION

(Up to 4 trees)

Map the area and have cultures made from roots of apparently healthy trees bordering the diseased trees, to determine just how much area has been invaded by the fungus. The fungus is usually present in several trees bordering the obviously diseased trees and may have spread to a number of trees below an originally diseased tree.

Isolate the area having diseased trees by putting up a temporary fence; permit no traffic of equipment, dogs, farm animals or people across the area. This is particularly important during periods when soil is wet and might be moved to healthy portions of the grove. *Do not irrigate this area.*

Fumigation

If the area is not too extensive (up to 4 trees), cut the trees back to the ground level and fumigate the soil to reduce or eliminate the fungus population. The fungus is not usually present in the aboveground parts of the tree, hence disposal of the trunk and branches presents no problem in the spread of the fungus in most cases. However, do not drag trunks and branches across infested soil into noninfested areas as the fungus could be spread in soil adhering to the trunks or branches. If trees are pulled, the fungus may spread to healthy trees if roots and attached soil are moved through the grove. Very rarely, the fungus causes cankers on the trunk, sometimes to a height of 3 or 4 feet, with accompanying oozing and production of white deposits of sugar. If cankers are present, burn the trunk.

The fungus population can be greatly reduced and possibly eliminated with heavy dosages of fumigants. *Fumigation has the most chance of success if it is applied as soon as possible after the disease appears in a grove—when only a few trees are affected.* Although high dosages of fumigants will kill the trees, they are necessary if the fungus population is to be greatly reduced.

Complete elimination of a fungus from soil, once it has become well established and spread over a wide area, is exceedingly difficult. Fumigation, coupled with other measures such as drying the soil by withholding irrigation water and replanting later with resistant crops, will appreciably reduce the fungus population.

The best fumigants

On the basis of present information, the most effective fumigants to reduce the root rot fungus are D–D, Telone, Mylone and Vapam 4-S or VPM. Methyl bromide is effective under nursery fumigation conditions as outlined previously, and also effective in light soils in the field.

1. D–D or TELONE. Inject D–D into

the soil at the rate of 150 gallons per acre or Telone at 120 gallons per acre. Make injections 6 inches deep and 12 inches apart. To obtain a dosage of 150 gallons per acre, inject approximately 17 milliliters (slightly more than ½ ounce of the liquid) in each of the holes; for 120 gallons use approximately 14 milliliters. Soil should be in good seed-bed planting condition at the time of injection for all fumigation treatments.

2. MYLONE. Use 4 pounds of 50 per cent formulation per 100 square feet of soil surface, spread evenly over the soil surface by means of a fertilizer spreader or other means, followed by 4 gallons of water per square foot.

3. VAPAM 4-S or VPM. Use 2 quarts of 30 per cent sodium methyldithio-carbamate formulation (Vapam 4-S or VPM) per 100 square feet of soil surface irrigated into the soil with 4 gallons of water per square foot. This is about 6 acre-inches of water.

This fungicide can be applied by 1) injection into sprinkler lines with a Prizer-type fertilizer injector or other apparatus; 2) with a proportioner on a hose; or 3) by sprinkling on the soil.

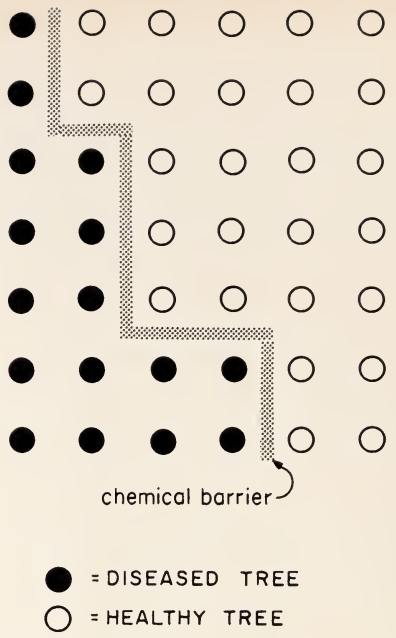
Arrange sprinklers inside of and around the margins of the area to be treated so you obtain complete and uniform coverage. If the soil is level, Vapam 4-S or VPM can also be applied in basins, using the same amount of material and water.

If methods 2 or 3 are used, a split application is suggested. Apply 2 pints of Vapam 4-S or VPM per 100 square feet followed by 2 gallons of water per square foot, then apply two more pints of fungicide followed by 2 more gallons of water per square foot.

CONTROLLING LARGE AREAS OF INFECTION

(More than 4 trees)

If the fungus has invaded an extensive area before the disease is detected, there are several means of retarding the spread of the disease or reducing the severity of the attack.



Chemical barriers show promise in retarding spread of the root rot fungus. As shown by this diagram, Vapam applied as a 5-foot wide barrier strip every 6 months, stopped the spread of root rot fungus from the infested area to the healthy trees.

Establish a barrier

Map the area and have laboratory cultures made to determine where the fungus has invaded the soil. Establish a barrier at least two tree rows beyond where culture results indicate the fungus to be present. This is necessary because the fungus may be present on roots of healthy-looking trees.

Two types of barriers can be used to retard the spread of the fungus; chemical and dry barriers. Here are some suggestions for applying these barriers:

Chemical barriers. Treat a strip 5 to 6 feet wide around the infested area with D–D, Telone, Vapam 4-S, VPM, or Mylone at the same rates previously discussed for control of small spots. Re-treat every 6 months.

Dry barriers. A dry barrier will retard spread of the root rot fungus because the fungus is sensitive to drying of the soil. Allow two rows of trees on the edge of the

Left: untreated tree. Right: tree treated with Dexon in irrigation water for 7 years. Both trees in similar condition at start of experiment; avocado root rot fungus present in soil under both trees for 7 years.

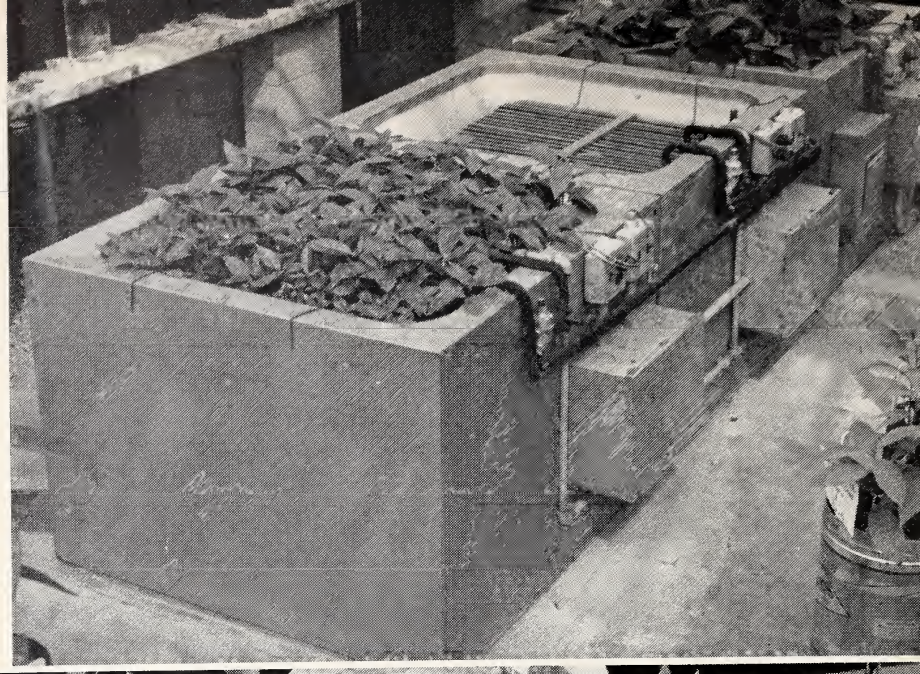
infested area to remove water from the soil. Do not irrigate these trees and the infested area. If possible, water the surrounding healthy trees only on the side away from the diseased trees. Maintain this as a permanently dry zone; remove trees in this zone as they die or no longer take water from the soil. Even though the dry barrier will be wet by winter rains, drying during the irrigation season will greatly retard the progress of the fungus. The fungus population is greatly reduced when soil moisture is extremely low.

If you employ chemical or dry barriers, establish diversion drains to prevent movement of the fungus in surface water from infected to healthy trees, where the diseased trees are above an uninfested section of your grove.

Treatment of diseased trees

Careful irrigation slows the spread of the disease and prolongs the life of affected trees because too much soil moisture favors root rot development. Affected trees use much less water because the small feeder roots are destroyed. In controlled experiments it has been shown that, at a soil temperature of 80° F, avocado trees in infested soil will use only one-fourth the amount of water used by trees in non-infested soil. Therefore, if all trees in a grove, healthy and diseased alike, are given the same amount of water in one irrigation, water will accumulate in the soil around the diseased trees and accentuate the disease situation. In controlled experiments, trees given twice as much water in the presence of the root rot fungus developed root rot more rapidly and severely than trees given the lesser amount of water.

Any practice that tends to reduce the period that free water may remain in the soil will reduce the severity of the disease. Such practices include: *selection of a site with good internal soil drainage; careful irrigation to prevent watering soil that is already wet; and surface and subsurface drains to remove rainfall and excessive moisture.* Tensiometers are useful to de-



Avocado collections from California and Latin America are tested for root rot resistance in tanks (upper photo) where seedlings are grown in aerated nutrient solution; they are then inoculated with the root rot fungus. Disease development is rapid and severe; 95 to 100 per cent of the roots of susceptible plants are rotted in 10 days. Lower photo shows healthy roots of seedlings prior to inoculation.

termine water use where root rot is present and to find out when and how much water to apply to diseased trees.

Soil fungicides. The use of soil fungicides is another means of combating root rot. Dexon (p-dimethylaminobenzenediazo sodium sulfonate) is giving good results in preventing further development of root rot in trees treated when they are in an early stage of disease. It is applied in the irrigation water or applied to the soil as a concentrated solution and immediately watered in. Also there is now a 5 per cent granular formulation available in California, which can be spread on the soil surface and watered in. The chemical does not persist in the soil so that repeated applications must be made. It is rapidly inactivated in sunlight. Residue analyses have shown that no Dexon residue accumulates in the fruit, and the chemical is now registered for use on avocado. Additional information is available from the Farm Advisor's offices in the avocado-producing counties.

Soil amendments. A number of years ago greenhouse tests showed that alfalfa meal, when mixed with soil infested with the root rot fungus, gave good control of the disease on small seedlings. Applications of alfalfa meal to large trees in the field have given inconsistent results. Recently alfalfa leaf meal has been found to be much more effective in the greenhouse than alfalfa stem meal. This aspect of soil amendments, or biological control, is being studied further.

Crop rotation

Replanting the infested soil to resistant plants is another way to deal with an infection caused by the root rot fungus. Although the fungus has a very wide host range, there are a number of plants that are not susceptible and can be used to replant such areas. These include citrus (all types), cherimoya, persimmon, all types of vegetables and most annual flower crops.

The macadamia tree is resistant to the root rot phase of the fungus but is susceptible to a trunk canker caused by the same fungus if the trunk is wounded. Canker is not common and can probably be largely prevented by not damaging the trunks of macadamia trees planted in infested soil and by spraying the lower trunks with Bordeaux mixture 5–5–100 as in control of citrus gummosis.

If a relatively small section of the avocado grove is removed, treatment of the soil with Telone, D–D, or methyl bromide will reduce the root rot fungus population and cut down the hazard to healthy avocado trees bordering the area from which

A highly resistant importation from Venezuela, Persea caerulea ("aguacatillo") at right is unaffected by root rot although it has been planted in soil heavily infested with the root rot fungus. Topa Topa seedlings (left) planted in the same soil, show severe damage. This Venezuelan import cannot be grafted on California avocados.

trees are removed. The resistant crop can then be planted. A barrier treatment might also be used to retard the spread of the fungus from the infested into noninfested nearby areas.

Resistant rootstocks

The method of control that has the greatest possibility of success in the long run is the development of a rootstock that is resistant to the root rot fungus. High resistance has been discovered in native Latin American trees related to the avocado, but these small-fruited, resistant types are not compatible with commercial avocado varieties.

Appreciable resistance has been found in the Duke variety and in several collections of native avocado types from Latin American areas. Some seedlings from Duke trees have at least moderate resistance. Cuttings from these Duke seedlings or from the Duke variety are more resistant than any of the commercial rootstocks.

Because of the importance of the program and because development of a satisfactory resistant rootstock is a laborious, long-term project, the collecting, testing and hybridization program has been expanded and accelerated. Seedlings are tested in nutrient solution in temperature-controlled tanks (see photo, page 14). Thousands of seedlings have been run through these tests in search of the ideal highly resistant, compatible type.

A cooperative program has been established with Mexico, in which seeds of avocado and other species of *Persea* are collected in many areas in Mexico and tested for resistance in the greenhouse at Chapingo, Mexico. This is a cooperative program between the Agricultural Department of the Mexican Government, the Postgraduate College of the National School of Agriculture, and the University of California. A cooperative arrangement for collecting seeds has also been developed with the government of Guatemala, through its Agricultural Experiment Station.

In brief . . .

TO PREVENT ROOT ROT:

- Demand clean nursery stock (clean seed, clean soil, clean culture)
- Plant in soil not infested with the root rot fungus
- Plant in soils with good internal drainage
- Prevent movement of water, soil, plants from infested to noninfested areas

TO CONTROL ROOT ROT:

Small areas (up to 4 trees)

- Sample the soil to determine fungus distribution
- Isolate the area
- Stop irrigating
- Fumigate the soil

Large areas (more than 4 trees)

- Sample the soil—establish barriers
- Irrigate carefully
- Replant with resistant crop

WARNING ON PESTICIDE RESIDUES

These recommendations for pest control are based on the best information currently available for each pesticide listed. Treatments based upon these recommendations should not leave residues that will exceed the tolerance established for any particular chemical. To avoid excessive residues, follow directions carefully with respect to dosage levels, number of applications, and minimum interval between application and harvest.

THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other properties or crops.

To simplify the information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

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